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ABSTRACT

A graphics terminal designed for use as a remote computer input/output terminal is described. Although the terminal is intended for use in teaching applications, it has several features which make it useful in many other computer terminal applications. These features include: a 10-inch square plasma display panel, permanent storage of information on the display screen without flicker, self-contained character and line generators, an optional random-access audio response unit, and a random-access slide projector. The terminal can send and receive data on voice grade telephone circuits. The unit has a character-writing speed of 180 characters per second and the capability of displaying up to 2048 characters on the screen. It has a line-drawing speed of more than 600 inches per second and a character repertoire of 256 characters. The operating modes of the terminal, including commands, are explained, as are possible sources of and the output word format for terminal-generated data. (JK)

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CERL REPORT X-15

MARCH, 1970
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A PLASMA DISPLAY TERMINAL

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EM 008 737

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A PLASMA DISPLAY TERMINAL*

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ABSTRACT

This report describes a graphics terminal designed for use as a remote computer input-output terminal. The terminal features a plasma display panel, self-contained character and line generators and the ability to communicate over voice grade telephone circuits.

*This work was supported in part by the Joint Services Electronics Program (U.S. Army, U.S. Navy, and U.S. Air Force) under Contract DAAB-07-67-C-0199; and in part by National Science Foundation Grant USNSF GJ 81.

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Frank Propst and Garrie Burr were responsible for the slide projector and the design of the terminal enclosure.

Leonard Hedges supervised the fabrication of the terminal electronics and was assisted in the actual construction by George Crawford, Fred Holy, and Rich Slavens.

Thanks are due Sandra Bowles, Jean Ciesa, and Terry Gabrielse for their help with the publication.

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CHAPTER 1 - DESCRIPTION

1.0 Introduction

This report describes the proposed student terminal (remote computer terminal), designed for use in the PLATO IV computer-based-education system. Although the terminal is intended for use in teaching applications, it has many features which make it useful in many other computer terminal applications. These features include:

1. A 10-inch square plasma display panel that is readable in a brightly lighted room without eyestrain.
2. Permanent storage of information on the display screen without flicker. Absolutely no refreshing of the display panel by the computer is required.
3. Self-contained character and line generators.
4. A character writing speed of 180 characters per second and the capability of displaying up to 2048 characters on the screen.
5. A line drawing speed in excess of 600 inches per second.
6. A character repertoire of 256 characters, 128 of which are alterable via the computer program.
7. The ability to transmit and receive data on voice grade telephone circuits.
8. A random access slide projector for rear projection of static information on the display screen.
9. Additional input-output channels for the control of auxiliary equipment.
10. An optional random-access audio response unit.

The single most expensive item in any cathode-ray tube (CRT) display system is the memory needed to refresh or "hold up" an image on the face of the CRT. As many as 4K 18-bit words of memory (1 us) may be required to "hold up" an image occupying as little as 2% of the available space on a display with 512

line resolution. At a cost of 5¢ per bit such a memory becomes a $3600 item. Even before including the costs of the CRT, the digital to analog (DA) converters, and the deflection amplifiers, all of which can easily add up to an additional $1000, a cost level has been reached that is prohibitive for most large users of graphic display terminals.

Fortunately, the plasma display panel[1,2] with its inherent capability storing information on the display screen eliminates entirely the costly items mentioned above. This inherent memory and the digital nature of the plasma panel offers for the first time the promise of low cost graphical display terminals. Preliminary estimates indicate, for example, that the terminal described in this report can be produced in quantity for less than $2500. This terminal cost is almost 1/3 less than the cost of just the memory required to operate a comparable graphical CRT display.

1.1 Terminal Description

A block diagram of the prototype terminal is shown in Figure 1.0. The terminal input section contains both a parallel and a serial input port. The parallel port is an optional feature used mainly for engineering purposes. At present, this port is designed to interface with a CDC 1604 Computer. The serial input port is designed to accept data arriving at a rate of 1200 bits/second in the form of a frequency-modulated (fm) signal, which permits

[1] D. L. Bitzer, and H. G. Slottow, "The Plasma Display Panel - A Digitally Addressable Display with Inherent Memory", Proceedings, Fall Joint Computer Conference, San Francisco, California, November 1966, p. 541.

[2] B. M. Arora, D. L. Bitzer, H. G. Slottow, and R. H. Willson, "The Plasma Display Panel: A New Device for Information Display and Storage", Proceedings 8th National Symposium of the Society for Information Display, May 1967, p. 1.

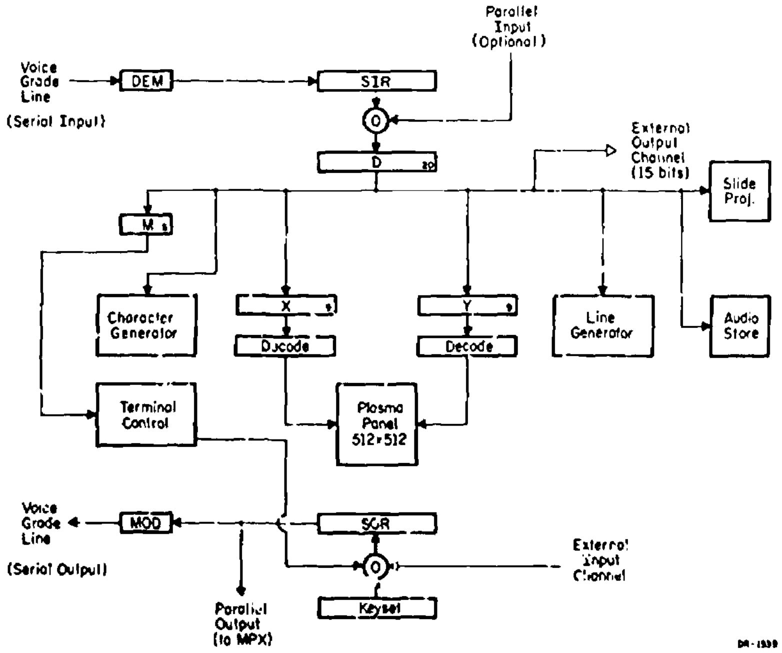

Figure 1.0 Termin l Block Diagram

the terminal to operate on voice grade (Schedule 4) telephone circuits. The terminal word size is 20 bits and therefore the terminal word rate is 60 words per second. The terminal word format is discussed in Chapter 2.

The demodulator recovers the data from the fm signal and shifts the data into the serial input register (SIR). After a full word has been assembled in the SIR it is transferred to the Data (D) Register.

The 20-bit D register is the distribution center of the terminal. From this register data may be transferred to all internal sections of the terminal as well as any external equipment connected to the terminal.

The 6 bit mode register (M) is analogous to the instruction register in a digital computer. This register directs the Terminal Control section in the processing of incoming data. Terminal Control provides the timing and control signals for controlling the flow of data within the terminal. Four modes of operation are available and are discussed in Chapter 2.

The data is displayed on a Digivue* Plasma Display Panel. This panel is a 10-inch square panel containing 512 addressable points along each axis or a total of 262,144 points. The address of any point on the panel is specified by the contents of the 9 bit X and Y registers. The outputs of these registers are sent to the decoding and driving circuits which drive the display panel.

The line generator contains the circuits used in plotting lines on the panel. Lines of any length may be drawn at the rate of 60 lines per second.

The character generator contains four memories each containing the points for plotting 64 characters or a total of 256 characters. Two of the memories are read-only memories (ROM) and two are random access (RAM).

*Trade-mark of Owens-Illinois, Inc.

In the latter case the memories are loaded by the computer with special character or graphical data as required by the terminal user. Characters are plotted at a rate of 180 per second.

A 64 character keyboard provides the terminal operator with an input link to the computer center. Data from the keyboard is entered into the serial output register (SOR). From the SOR data is shifted into the modulator where it is encoded as an fm signal for transmission to the computer center.

Two additional inputs to the SOR are provided. One port permits Terminal Control to transmit terminal condition information to the computer while the other port provides access to the computer center for externally connected equipment.

In many installations several terminals may be grouped together and share a common link with the computer center. In such cases, data is taken from the parallel output port on the SOR and transferred to a multiplexor where it is encoded and transmitted to the center.

1.2 Auxiliary Equipment

Three 15 bit output channels are provided to permit operation of external equipment.

One channel is used to transmit data to a random access slide projector which can project slides on the rear of the plasma display panel. The slide projector will contain a 256 slide memory with an access time of .2 second.

A second channel may be used to address an audio response unit. The audio unit will, upon command from the computer center, play back a message to the terminal operator. Up to 15 minutes of prerecorded audio messages

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may be available with an average access time of .5 second.[3]

Other types of equipment which might be attached to the terminal include printers, or other hard copy devices and various types of data acquisition and recording equipment.

[3] D. L. Bitzer and D. Skaperdas, "A Random Access Audio Device", CERL Report X-13 (Computer-Based Education Research Laboratory, University of Illinois), (in preparation).

CHAPTER 2 - OPERATING MODES

2.0 Word Format

The data to be processed by the terminal consists of 20 bit words with the format shown in Figure 2.0.

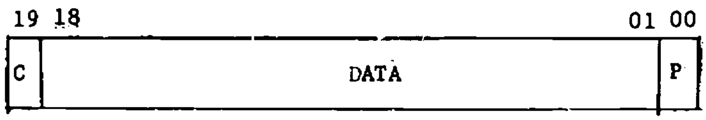


Figure 2.0 Terminal Word Format

Bit 00	Parity bit - odd parity
Bits 01 - 18	Data
Bit 19	Control bit - 0 = control word - 1 = data word

Terminal words may be of two types; control words and/or data words. Data words (C = 1) contain the data to be processed by the terminal while control words (c = 0) are instructions used to establish certain conditions within the terminal.

2.1 Control Word

The control word format is shown in Figure 2.1.

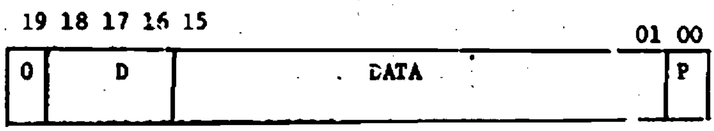


Figure 2.1 Control Word Format

Bits 01 - 15	Data
Bits 16 - 18	Destination of data within the terminal

The destinations are described below.

D = 000 (NOP)

19	18 17 16	15 ... 01	00
0	0 0 0	0------------------------------0	0

This word is a NOP (no-operation) instruction. The word is input by the terminal but the terminal condition is not altered in any way.

D = 001 (LDM) Load Mode

19	18 17 16	15	14	13 ... 07	06 ... 01	00
0	0 0 1	EXI	WC	WORD COUNT	MODE WORD	P

This instruction loads the Mode register (M) with bits 01-06. In addition, if bit 14 (WC) is a "1" the Word Count register will be loaded with bits 07-13. The mode word is described in Section 2.2 and the Word Count in Section 2.8. Bit 15 is used to activate the external input channel. If this bit is a "1" data may be transmitted from external devices, if it is "0" data may be transmitted only by source, internal to the terminal (See Chapter 3).

D = 010 (LDC) Load Co-ordinate

19	18 17 16	15 ... 11	10	09 ... 01	00
0	0 1 0		X/Y	X(Y)	P

This instruction loads the X register (bit 10 = 0) or the Y register (bit 10 = 1) with bits 01-09. Bits 11-15 are unused.

D = 011 (LDE) Load Echo

19	18	17	16	15 — 08	07 — 01	00
0	0	1	1		ECHO	P

This instruction loads the terminal output register (SOR) with bits 01-07. This word is then transmitted back to the computer center.

Programming Note: This instruction should not be sent to the terminal at a rate greater than once every 32 words. (Once every 64 words if external input devices are present at the terminal.) Exceeding this rate may cause erroneous data to be returned to the computer center.

D = 100 (LDA) Load Memory Address

19	18	17	16	15 — 11	10 — 01	00
0	1	0	0		MEMORY ADDRESS	P

This instruction loads the Memory Address Register (MAR) with bits 01-10. Bits 11-15 are unused. This data word specifies the first storage address to be used upon entry into a Mode 2 operation. See Section 2.5.

D = 101 (SSL) Load Slide

19	18	17	16	15 — 01	00
0	1	0	1	SLIDE ADDRESS	P

This instruction is used to display a slide on the plasma panel. Bits 01 - 15 are sent to the slide projector when they are used for slide addressing or other projector control operations.

D = 110 (AUD) Load Audio

19	18	17	16	15 – 01	00
0	1	1	0	AUDIO DATA	P

This instruction is used to control the audio response unit. Bits 01 - 15 are sent to the audio unit where they may be used for message addressing or other control operation.

D = 111 (EXT) Load External Channel

19	18	17	16	15 – 01	00
0	1	1	1	EXTERNAL DATA	P

This instruction transfers bits 01 - 15 to any equipment attached to the external output channel of the terminal.

2.2 Mode Word

For each mode of terminal operation there is an associated mode word which directs the terminal processing of incoming data. Once placed in any given mode the terminal remains in that mode until receipt of a new LDM instruction. The mode word format is shown in Figure 2.2.

06	05	04	03	02	01
	M_1	M_0	W/E_1	W/E_0	S

Figure 2.2 Mode Word Format

Bit 01	Screen Command. If this bit is a "1", the entire display panel is erased at the time the Mode Word is loaded into the M register.
Bits 02 - 03	Select write or erase function as follows:

W/E_1	W/E_0	
X	0	Erase
0	1	Write
1	1	Write; suppress all background erase operations. This operation is described in more detail in Section 2.6.

Bits 04 - 05	Specify operating mode
Bit 06	This bit is unused.

2.3 Mode 00

Mode 0 is a point plotting mode. Each mode 0 data word (Figure 2.3) specifies the address of a point on the panel to be written or erased. The W/E_0 bit in the mode word determines which operation is performed.

19	18 ... 10	09 ... 01	00
1	X	Y	P

Figure 2.3 Mode 0 Data Word

2.4 Mode 01

Mode 1 is a line drawing mode. Each data word, Figure 2.4, specifies the terminal coordinates of a line, the origin of which is contained in the X and Y registers.

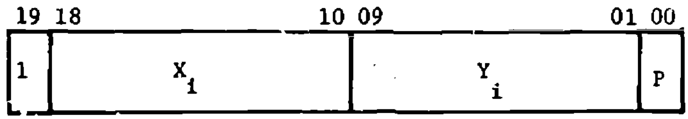


Figure 2.4 Mode 01 Data Format

The terminal point of a given line is also interpreted as the origin of the next line. Line origins may be relocated, however, by the use of the LDC command without exiting from Mode 01.

An example of a Mode 01 operation is shown in Figure 2.5

2.5 Mode 10

Mode 2 is a load terminal memory mode. Each mode 2 data word (Figure 2.6) contains a 16 bit word to be stored in the memory location specified by the present contents of the memory address register (MAR). Up to 1024 16 bit words may be stored in the the terminal. After the data has been stored

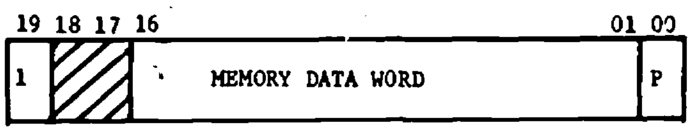


Figure 2.6 Mode 2 Data Word

the MAR is automatically incremented by 1. Thus, data may be stored sequentially in memory by transmitting only Mode 2 data words. The contents of the MAR may be changed at any time via the LDA instruction.

The data, when displayed on the panel, appears as a vertical column with bit 01 at the bottom and bit 16 at the top. The stored data is displayed via Mode 3 which is described in the next section.

2.6 Mode 011

Mode 3 is a character plotting mode. The data words in this mode contain 3-6 bit character codes as shown in Figure 2.7.

19	18 13	12 07	06 01	00
1	CHAR 1	CHAR 2	CHAR 3	P

Figure 2.7 Mode 3 Data Word

Four 64 character memories are provided in the terminal. Memories M_0 and M_1 are read-only memories (ROM) which contain the characters shown in Table 2.1. Memories M_2 and M_3 each contain 512 words, 16 bits, the contents of which may be loaded via Mode 2. The contents of M_2 and M_3 are interpreted by Mode 3 as 64 arrays of 8 x 16 bits each. Thus, a character called from M_2 or M_3 actually causes the contents of 8 succeeding memory locations to be displayed on the panel.

Characters from M_0 and M_1 are also plotted within an 8 x 16 array which includes character and line spacing. See Figure 2.8.

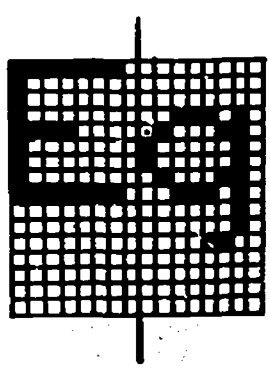
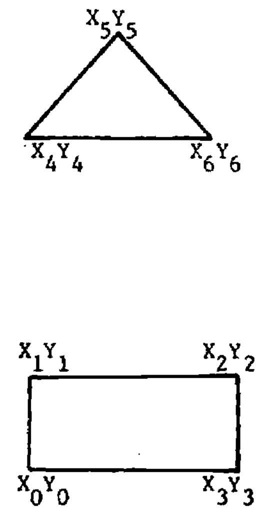


Figure 2.8 Character Matrix

0	LDC	0	X_0	P
0	LDC	1	Y_0	P
1	X_1		Y_1	P
1	X_2		Y_2	P
1	X_3		Y_3	P
1	X_0		Y_0	P
0	LDC	0	X_4	P
0	LDC	1	Y_4	P
0	X_5		Y_5	P
0	X_6		Y_6	P
0	X_4		Y_4	P

DATA



DISPLAY

Figure 2.5 Mode 01 Example

BCD Code	M_0	M_1	M_2	M_3
00	SPACE	SPACE		
01	A	#		
02	B	$		
03	C	%		
04	D	&		
05	E	→		
06	F	←		
07	G	↑		
10	H	↓		
11	I	–		
12	J	|		
13	K	||		
14	L	˜		
15	M	∿		
16	N	¨		
17	O	ˆ		
20	P	∞		
21	Q	∘		
22	R	⇀		
23	S	'		
24	T	α		
25	U	β		
26	V	∂		
27	W	μ		
30	X	¶		
31	Y	σ		
32	Z	ω		
33	:	{		
34	;	}		
35	'	Δ		
36	?	θ		
37	!	Σ		

BCD Code	M_0	M_1	M_2	M_3
40	"	∅		
41	a	1		
42	b	2		
43	c	3		
44	d	4		
45	e	5		
46	f	6		
47	g	7		
50	h	8		
51	i	9		
52	j	≡		
53	k	=		
54	l	≈		
55	m	∿		
56	n	≠		
57	o	>		
60	p	<		
61	q	≥		
62	r	≤		
63	s	x		
64	t	*		
65	u	/		
66	v	+		
67	w	-		
70	x	√‾		
71	y	o		
72	z	[		
73	(	]		
74	)	,		
75	,	.		
76	.			
77	UNCOVER	UNCOVER	UNCOVER	UNCOVER

Table 2.1 Character Codes

Character write/erase is controlled by the write/erase bits in the mode word. If $W/E_0 = 1$, characters are written; if $W/E_0 = 0$, characters are erased. If $W/E_1 = 0$, the background or normally unfilled portion of each character matrix will be erased, if $W/E_1 = 1$ the background remains unaltered.

Up to 32 lines of 64 characters each may be plotted for a total of 2048 characters. In comparison, a typical page of double spaced type consists of 27 lines of 72 characters or a total of 1944 characters.

2.7 Control Characters

The "uncover" code (77) is used to gain access to 12 control characters. These characters are useful in controlling display format in Mode 3 operations.

Upon receipt of a 77 code, the terminal interprets the next character code as a control character rather than a memory address. Following execution of the control character normal Mode 3 operations are resumed. A description of each control function is given below.

Uncover (77)

This code instructs the terminal to obey the next character address as a control function. If several uncover codes are sent in sequence, the first non-uncover code will be treated as the control character.

Backspace (10)

This character decreases by 8 the panel x address, i.e., moves one character position to the left. A backspace over a displayed character does not erase the character.

Tab (11)

This character increases by 8 the panel x address, i.e., moves one character position to the right. A tab over a displayed character does not erase the character.

Line Feed (12)

This character decreases by 16 the panel y address, i.e., moves down one character position. A line feed over a displayed character does not erase the character.

Vertical Tab (13)

This character increases by 16 the panel y address, i.e., moves up one character position. A vertical tab over a displayed character does not erase the character.

Form Feed (14)

This character sets the panel address to the upper left corner (x = 0, y = 496). This is the first character position on the top line of the display. No displayed data is erased in this operation.

Carriage Return (15)

This character clears (sets to 0) the panel x address and decreases by 16 the y address. The screen address is thus set to the first character position on the line immediately below the present line. No displayed data is erased in this operation.

Superscript (16)

This character increases the panel y address by 5. All characters received following this code appear as shown in Figure 2.9. This selection may be removed by receipt of a subscript (17) code. No data is erased in a subscript operation.

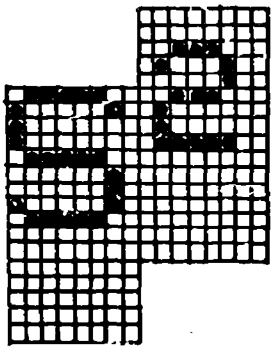


Figure 2.9 Superscript Operation

Subscript (17)

This character decreases by 5 the panel y address. All characters received following this code appear as shown in Figure 3.0. This character may be used to remove a superscript selection (16) and the superscript code may be used to remove this selection. No data is erased in a superscript operation.

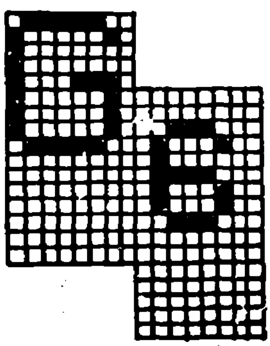


Figure 3.0 Subscript Operation

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Select M_0 (20)

This code selects character memory 0. All succeeding characters will be read from the memory until receipt of a different memory select code.

Select M_1 (21)

This code selects character memory 1. All succeeding characters will be read from this memory until receipt of a different memory select code.

Select M_2 (22)

This code selects character memory 2. All succeeding characters will be read from this memory until receipt of a different memory select code.

Select M_3 (23)

This code selects character memory 3. All succeeding characters will be read from this memory until receipt of a different memory select code.

2.8 Error Control

Contained within the terminal is a 7 bit Word Count (WC) register, which maintains a record of the number of non-NOP words received by the terminal. Each time a non-NOP word is transferred into the terminal the Word Count is incremented by 1.

Upon receipt of a word with a parity error the terminal enters the ABORT mode of operation. In this mode the terminal repeatedly (approximately twice per second) transmits the contents of the WC to the computer. The WC will contain the address of the word containing the error.

Once in the ABORT mode the terminal will refuse to accept any further information except for a LDM instruction with bit 14 a "1". Receipt of this word will clear the ABORT mode and return the terminal to normal operation.

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CHAPTER 3 TERMINAL GENERATED DATA

3.0 Data Sources

Data may be generated by any of three sources within the terminal or by an external device connected to the external input channel. Internal sources of data are:

1. The Word Count register (See Section 2.8)
2. The echo code. See LDE instruction in Section 2.1
3. The keyboard. The keyboard contains 64 keys as shown in Figure 3.0 and has the coding shown in Figure 3.1

3.1 Output Word Format

The data transmitted from the terminal consists of 9 bit words with the format shown in Figure 3.2.

Figure 3.2 Keyset Word Format

Bit 00	Parity bit - odd parity
Bits 01-07	Data Field
Bit 08	Identifier Bit. This bit identifies the data as follows:
	0 = valid piece of data from keyboard, external channel, or echo code.
	1 = data field contains word count specifying a word which arrived at the terminal containing an error.

Standard Keyboard

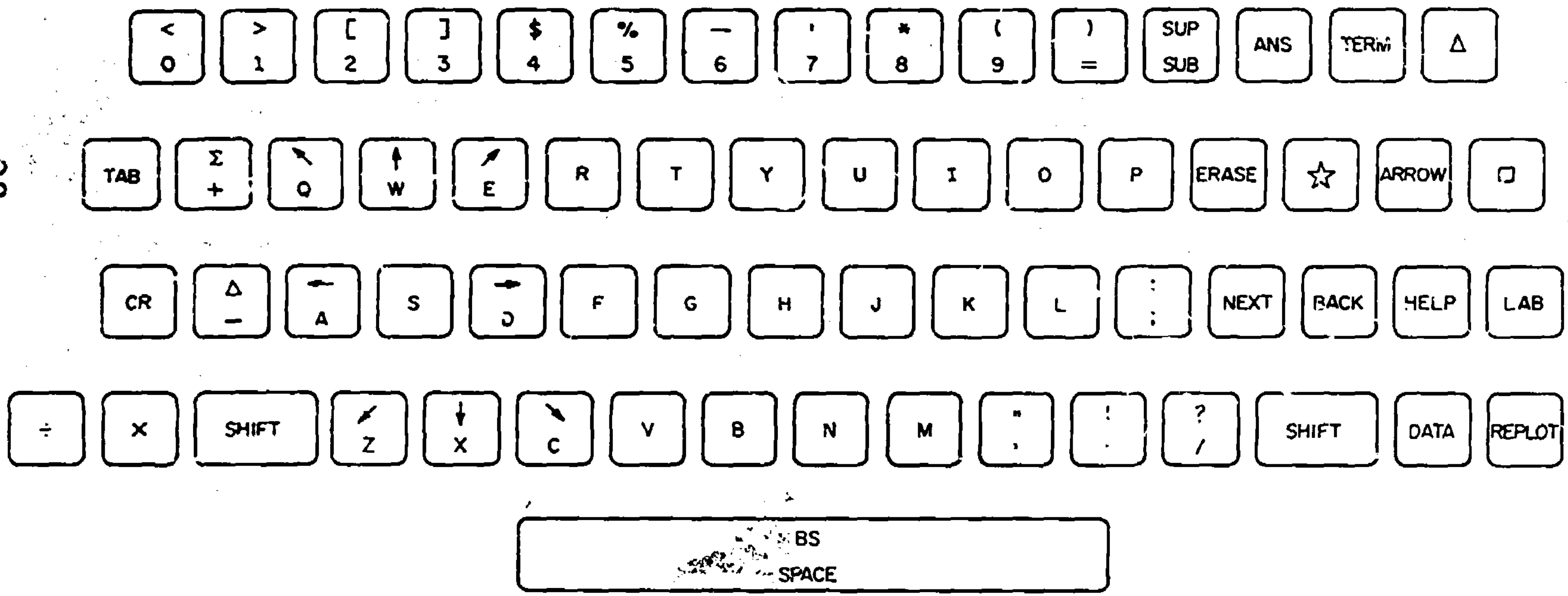
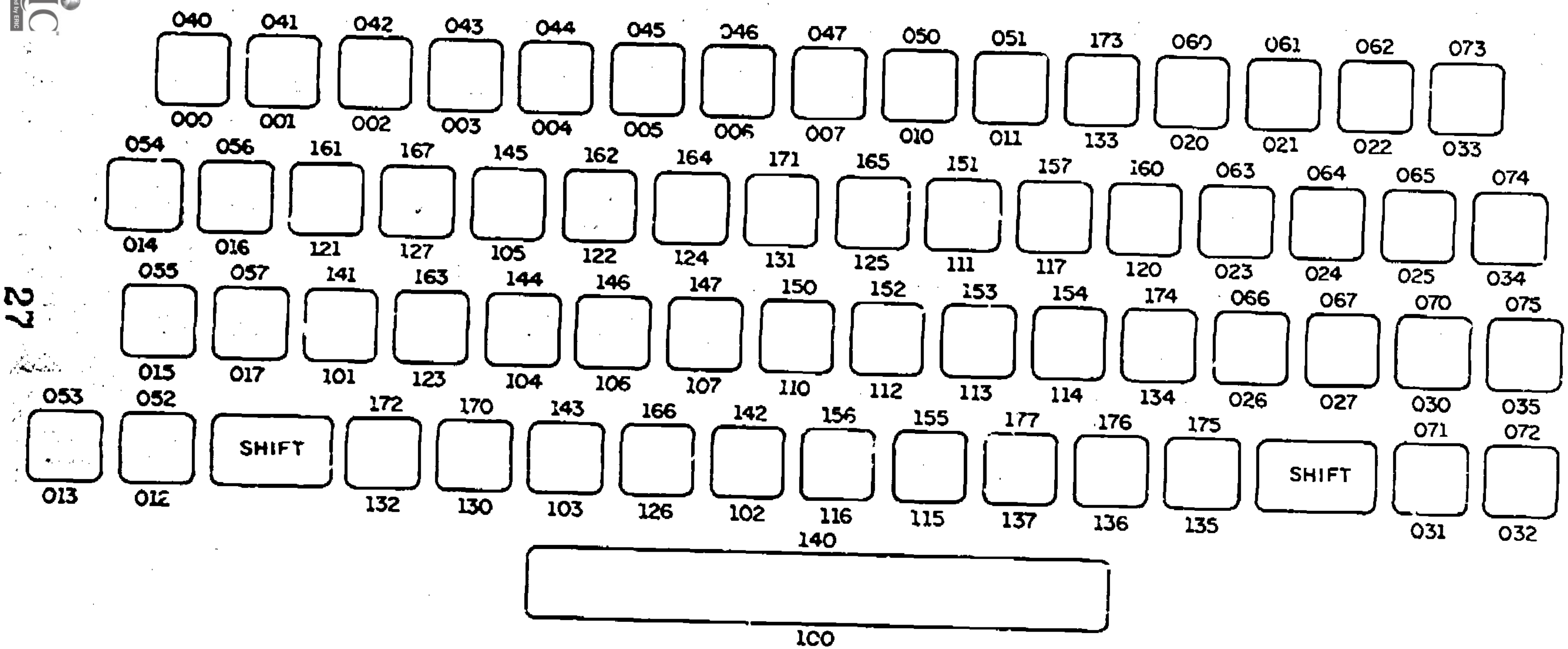


Figure 3.0 KEYBOARD



NOTE: 1. Each key has two different inputs. The octal number below the box is the input when a key is pressed singly (normal state), and the number above the box is the input when the "Shift" key is held down as a key is pressed (shift state).

The "Shift" key alone does not initiate input data transfer, but merely causes an addition of 040 (octal) to a normal input.

2. There is a total of 124 different inputs.

3. The input codes 036, 037, 076, and 077 are not used.

Figure 3.1 KEYBOARD CODING

Where several terminals (up to 32) share a common link to the computer center the data is sent to a multiplexor which assigns a terminal identity code and adjusts the parity bit before transmitting the data on to the center. In this case, the data has the format shown in Figure 3.3. Except for the identity code, bit assignments are the same as in Figure 3.2.

13 — 09	08	07 — 01	00
TERMINAL IDENTITY	D/E	DATA	P

Figure 3.3 Multiplexed Word Format

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3 Chief of Naval Research
Code 458
Department of the Navy
Washington, D.C. 20360

1 Director
ONR Branch Office
495 Summer Street
Boston, Massachusetts 02210

1 Director
ONR Branch Office
219 South Dearborn Street
Chicago, Illinois 60604

1 Director
ONR Branch Office
1030 East Green Street
Pasadena, California 91101

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Office of Naval Research
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13. ABSTRACT

This report describes a graphics terminal designed for use as a remote computer input-output terminal. The terminal features a plasma display panel, self-contained character and line generators and the ability to communicate over voice grade telephone circuits.

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Character Generator						
Line Generator						

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